SOUND ANALYSIS FOR RESPIRATORY HEALTH MONITORING IN COMMERCIAL PIGGERIES

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Respiratory pathologies have a high prevalence in intensive pig farming and cough is their principal symptom. It is well-known that, under intensive breeding conditions, it is very unlikely for a pig to reach the slaughter weight without having shownany kind of respiratory infection. Higher mortality and drop in production for reduced feed conversion and growth rate, are often related to expensive veterinarian intervention costs. The economic side of this problem is particularly relevant for farmers and they face diseases administrating large spectrum antibiotics mass therapy which helps for antibiotic resistance in both animals and meat consumers. In nowadays intensive livestock farming the high density of breeded animals helps a rapid spread of the disease which is not parallely followed by punctual observation of animals. Cough is a clear marker in case of respiratory disease warning the health status. It is common practice by veterinarians to assess cough sounds, by audio monitoring, in pig houses for diagnostic purposes. A limitation to this technique stands in the short observational period in both time and space. To achieve this goal, there have been attempts to identify the characteristics of coughing in animals (Van Hirtum and Berckmans, 2002, 2002; Ferrari et al., 2008, 2009, 2010) and automatically identify and localize cough sounds in field recordings (Aerts et al., 2005; Van Hirtum and Berckmans, 2001, 2003, 2003, Exadaktylos et al., 2009, Silva et al., 2008, 2009). This paper wants to show an overview on the highlights of these ten years research in the field of sound analysis for health monitoring in piggeries focusing especially on the last two years results.

In a first study, in laboratory conditions, algorithms have been developed to recognise pig cough sounds; they were applied to a sound-database of 5319 individual sounds including animal's vocalisations, background-noises and 2034 coughs. This resulted in a positive cough-recognition of 92%. Afterwards studies focused on the acoustic characterization of coughs according to the type of infection (dry cough, moist cough, upper or lower respiratory tract), experiments were leaded both in lab and field conditions and more than 500 Gb of coughs sounds have been labelled and analysed in terms of Peak frequency, fundamental frequency, RMS and duration in order to understand which acoustic parameter was more significant as a discriminant. In the last two years, the experiments were focusing on the development of real time coughs warning systems coupling cough recognition with sound localization. Respiratory disease was strictly investigated along several production cycles in swine piggeries. Biotic and abiotic factors have been also investigated like airborne bacteria and viruses, dust, ammonia and climate parameters to understand their role in the outburst of respiratory diseases and in the type of cough.

Cough recognition was based on frequency domain and duration of the signal. This technique evaluates fuzzy c-means clustering to parts of the training signals (prelabelled coughs) and provides a frequency content reference that mirrors the characteristics of sick pig cough. It has been shown that pig sounds have dominant frequencies below 10 kHz. It is therefore important to eliminate those frequencies that contain no useful information for the present application. In this regard, a 10th order Butterworth filter with pass band 100–10,000 Hz is used. Then, as is common practice in signal processing, to reduce edge effects and spectral leakage each frame is passed through an N-point (we use N = 128) Hanning window. Sound fragments that are closer than 100 ms to each other be considered as a single sound. Furthermore, the length of each sound contains information that can be

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used in classification. Screams and grunts, for example, are longer sounds and can last for up to a few seconds. Coughs on the other hand are sharp sounds that usually last from 200 ms up to 600 ms. Sounds that are longer than 600 ms or shorter than 200ms are therefore considered as non-cough sounds and ignored from the rest of the process. Based on such an estimation of the actual sound signal, an attempt to form a classifier is made. In this regard, it is observed that the positions of the AR parameters in a three dimensional space for the pre labelled sounds can serve as an adequate and computationally efficient classifier. It is suggested that when plotting the AR parameters on the space, those that result from sick coughs form a well defined cluster. 88% of the sick coughs are correctly identified (12% false negatives), achieving a 92% of correct overall classification rate (with 6.8% false positive classifications).

For cough localization the time difference in arrival time of a sound signal between multiple microphones was used. To assess the accuracy of the method, estimated positions of a reference sound were compared with real positions in various microphone configurations. All the configurations showed good position estimation, with mean error between 1.5 and 0m, and a maximum SEM of 0.4 m. After mapping the locations in the stable, three hazard zones could be identified. This information can be used for visualizing the spread of respiratory diseases and eventually contribute to the reduction of the use of antibiotics by means of selective and early treatment of single pens instead of the whole compartment.

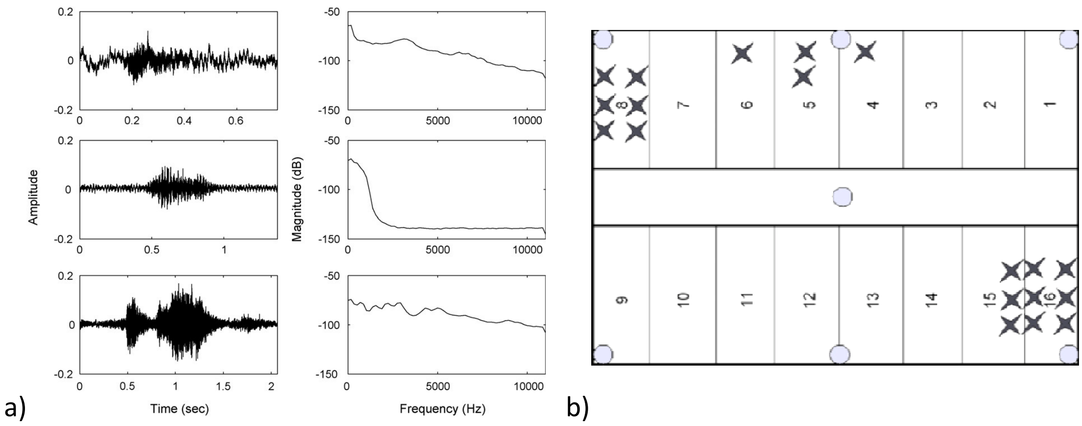

Figure 1: a) Time–signal (left column) and frequency content (right column) for a sick cough (top row), a grunt (middle row) and a scream (bottom row); b) Mapped cough attacks during a field experiment (the number of stars indicates the number of cough attacks recorded in that pen, the circles indicate the position of the microphones)

The combination between cough sounds automatic recognition and localization together with sanitary and environmental parameters allows great knowledge of the respiratory disease available to develop real-time applications that would speed up the diagnosis and treatment process and improve animal welfare in pig houses. In particular, the ability of detecting and localizing cough sounds and the increasing importance of animal welfare and monitoring has in the final part of this research brought to an automatic monitoring system that will help both farmers and veterinarians to achieve continuous feedback on the pigs’ condition by automatic on-line monitoring and hopefully contribute to the reduction of the use of antibiotics by means of selective and early treatment of single pens instead of the whole compartment.